MOTOR DRIVE CIRCUIT
AND ELECTRIC COMPRESSOR HAVING THE SAME

BACKGROUND OF THE INVENTION

The present invention relates to a motor drive circuit for driving an electric motor in an electric compressor and to an electric compressor with the motor drive circuit.

Unexamined Japanese Patent Publication No. 2002-155863 discloses a conventional electric compressor. For example, referring to FIG. 5, a diagram illustrates a front end view of a motor compressor or an electric compressor 100 according to a prior art. A compressor housing 101 forms an outer shell of the motor compressor 100. An electric motor 102 and a compression mechanism 103 are accommodated in the compressor housing 101. The compressor housing 101 includes a cylindrical circumferential wall 101a around a central axis L of the motor compressor 100, and a motor drive circuit 104 is arranged outside the circumferential wall 101a. The motor drive circuit 104 includes an inverter and the like for driving the electric motor 102. A casing seat 105 has a planar fixing surface 105a and is provided on the circumferential wall 101a of the compressor housing 101. A planar casing 106 for accommodating the motor drive circuit 104 is joined to the fixing surface 105a of the casing seat 105.

An unwanted feature is that the motor drive circuit 104 largely protrudes in the transverse direction of the compressor housing 10 because the cylindrical circumferential wall 101a of the compressor housing 101 is different in shape from the planar casing 106 of the motor drive circuit 104. Accordingly, the motor compressor 100 is relatively large in size in the radial direction of the central axis L.

Additionally, the casing seat 105 needs to be provided on the circumferential wall 101a of the compressor housing 101 to compensate for the difference in shape between the cylindrical circumferential wall 101a and the planar casing 106. Thus, the motor compressor 100 becomes heavy by the mass of the casing seat 105. Furthermore, for example, when the compressor housing 101 is manufactured integrally with the casing seat 105 by die-casting, some trouble such as a mold cavity is possibly produced at the thick portion of the casing seat 105. Therefore, there is a need for a motor drive circuit and an electric compressor with the motor drive circuit that contribute to reducing the size and weight of the electric compressor.

SUMMARY OF THE INVENTION

In accordance with the present invention, a motor drive circuit for driving

an electric motor in an electric compressor has a substrate and a plurality of electrical components. The compressor includes a compressor housing having a circumferential wall around a central axis of the compressor. The circumferential wall has a substantially cylindrical surface. The substrate is arranged outside the circumferential wall and includes a first portion and a second portion. The first portion is closer to the central axis than the second portion. The electrical components are mounted on the substrate on the near side relative to the central axis and include short electrical components that have relatively short height from the substrate and tall electrical components that have relatively tall height from the substrate. The electrical components line the cylindrical surface of the circumferential wall in such a manner that the short and tall electrical components are respectively arranged at the first and second portions.

Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of the present invention that are believed to be novel are set forth with particularity in the appended claims. The invention together with objects and advantages thereof, may best be understood by reference to the following

description of the presently preferred embodiments together with the accompanying drawings in which:

FIG. 1 is a longitudinal cross-sectional view of a motor compressor according to a preferred embodiment of the present invention;

FIG. 2 is a side view of the motor compressor according to the preferred embodiment of the present invention;

FIG. 3 is a partially enlarged cross-sectional view that is taken along the line I-I in FIG. 2 in a state when an electric motor is detached;

FIG. 4 is a partially enlarged cross-sectional view of a motor compressor according to an alternative embodiment of the present invention; and

FIG. 5 is a front end view of a motor compressor according to a prior art.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred embodiment of the present invention will now be described in reference to FIGs. 1 through 3.

Now referring to FIG. 1, a diagram illustrates a longitudinal cross-sectional view of a motor compressor or an electric compressor 10 according to the preferred embodiment of the present invention. A compressor housing 11 forms an outer shell of the motor compressor 10 and includes a first housing element 21 and a second housing element 22. The first housing element 21 has a substantially cylindrical circumferential wall 23 and an end wall that is formed on the left end of the circumferential wall 23 in the drawing. The first housing element 21 is die-cast in an aluminum alloy. The second housing element 22 forms a cylinder with an end wall on the right end in the drawing and is die-cast in an aluminum alloy. The first and second housing elements 21, 22 are fixedly connected with each other so that a closed space 24 is defined in the compressor housing 11.

A rotary shaft 27 is rotatably supported by the first housing element 21 in the closed space 24 and has a central axis of rotation that is identical to the central axis L of the motor compressor 10. The circumferential wall 23 of the first housing element 21 surrounds the central axis L of the motor compressor 10.

An electric motor 25 and a compression mechanism 26 are accommodated in the closed space 24. The electric motor 25 is a brushless direct current type or a brushless DC type and includes a stator 25a and a rotor 25b. The stator 25a is fixedly connected to an inner surface 23a of the circumferential

wall 23 of the first housing element 21. The rotor 25b is provided on the rotary shaft 27 and is arranged inside the stator 25a. The electric motor 25 rotates the rotary shaft by electric power that is supplied to the stator 25a.

The compression mechanism 26 is a scroll type and includes a fixed scroll member 26a and a movable scroll member 26b. As the movable scroll member 26b orbits relative to the fixed scroll member 26a in accordance with the rotation of the rotary shaft 27, the compression mechanism 26 compresses refrigerant gas or fluid. An outlet 32 is formed in the second housing element 22 for discharging the compressed refrigerant gas to an external refrigerant circuit, which is not shown in the drawing.

As the electric motor 25 drives the compression mechanism 26, the refrigerant gas in relatively low temperature and relatively low pressure is introduced from the external refrigerant circuit into the compression mechanism 26 through the electric motor 25. The introduced refrigerant gas is compressed to have relatively high temperature and relatively high pressure by the compression mechanism 26. Then, the refrigerant gas is discharged to the external refrigerant circuit through the outlet 32. Incidentally, the refrigerant gas in relatively low temperature from the external refrigerant circuit cools the electric motor 25 as it passes by the electric motor 25.

Now referring to FIG. 2, a diagram illustrates a side view of the motor compressor 10 according to the preferred embodiment of the present invention. An inlet 31 is formed in the first housing element 21. The refrigerant gas is introduced from the external refrigerant circuit into the compressor housing 11 through the inlet 31.

Now referring to FIG. 3, a diagram illustrates a partially enlarged cross-sectional view that is taken along the line I-I in FIG. 2. An outer surface 23b of the circumferential wall 23 is mostly formed along a cylindrical surface R having the central axis L. The first housing element 21 partially includes an accommodating portion 36. The accommodating portion 36 is provided on a portion of the outer surface 23b of the circumferential wall 23 and defines an accommodating space 35 inside. The accommodating portion 36 includes a frame-shaped side wall 37 and a cover member 38. The side wall 37 is integrally formed with the circumferential wall 23 and extends from the outer surface 23b. The cover member 38 is fixedly connected to the distal end surface of the side wall 37 by a fixing frame 40. The cover member 38 forms a thin plate and is made of metal such as an aluminum alloy. A seal member 39 is interposed between the distal end surface of the side wall 37 and the outer peripheral portion of the cover member 38 for sealing the accommodating space 35.

The outer surface 23b of the circumferential wall 23 defines a bottom

surface 35a of the accommodating space 35. In other words, the bottom surface 35a is formed on the left end of the accommodating space 35 in the drawing. The inner surface of the side wall 37 defines a side surface 35b of the accommodating space 35. Namely, the first housing element 21 defines the bottom and side surfaces 35a, 35b of the accommodating space 35. The cover member 38 defines a top surface 35c of the accommodating space 35. In other words, the top surface 35c is formed on the right end of the accommodating space 35 in the drawing.

A motor drive circuit 41 is accommodated in the accommodating space 35 in the accommodating portion 36 for driving the electric motor 25. The motor drive circuit 41 includes an inverter and supplies the stator 25a of the electric motor 25 with electric power based on a command from an air conditioner ECU, which is not shown in the drawing. Incidentally, the refrigerant gas cools the motor drive circuit 41 as it is introduced from the external refrigerant circuit to the compression mechanism 26 through the electric motor 25.

The motor drive circuit 41 includes a planar substrate 43 and a plurality of electrical components 44. The substrate 43 is fixedly connected to the circumferential wall 23 by a fastener, such as a bolt, which is not shown in the drawing. The substrate 43 is substantially in parallel with the central axis L of the motor compressor 10. The electrical components 44 are respectively mounted on surfaces 43a, 43b of the substrate 43. Namely, the electrical components 44 are

respectively mounted on the substrate 43 on the near and far sides relative to the central axis L. Incidentally, the electrical components 44 include electrical components 44A through 44E and other electrical components, which are not shown in the drawing.

The electrical components 44 include known components for constituting the inverter. That is, the electrical components 44 include a switching device 44A, an electrolytic condenser 44B, a transformer 44C, a driver 44D, a fixed resistance 44E and the like. The driver 44D is an integrated circuit chip or an IC chip for intermittently controlling the switching device 44A based on a command from the air conditioner ECU.

The switching device 44A has a height of h3 from the substrate 43 and is mounted on the surface 43a of the substrate 43, that is, on the substrate 43 on the near side relative to the central axis L. Some of the electrical components 44 are shorter than the switching device 44A if they are mounted on the same surface. The shorter electrical components 44 correspond to second electrical components. Only the above shorter electrical components 44 are mounted on the surface 43b of the substrate 43, that is, on the substrate 43 on the far side relative to the central axis L. The above shorter electrical components 44 include the driver 44D and the fixed resistance 44E.

Some of the electrical components 44 have heights of h1, h2 from the substrate 43 and are taller than the switching device 44A. The taller electrical components 44 and the switching device 44A are mounted on the surface 43a of the substrate 43, that is, on the substrate 43 on the near side relative to the central axis L. The taller electrical components 44 correspond to first electrical components. The taller electrical components 44 include the electrolytic condenser 44B and the transformer 44C. Accordingly, among the electrical components 44 on the surface 43a of the substrate 43, the switching device 44A corresponds to a short electrical component that has a relatively short height of h3 from the substrate 43, and the electrolytic condenser 44B and the transformer 44C correspond to tall electrical components that have relatively tall heights of h1, h2.

In the preferred embodiment, the electrical components 44 on the surface 43a are arranged as follows. The short electrical components such as the switching device 44A are arranged at the middle portion of the surface 43a of the substrate 43. The middle portion of the surface 43a of the substrate 43 corresponds to a first portion thereof. The tall electrical components such as the electrolytic condenser 44B and the transformer 44C are arranged at both ends of the surface 43a, that is, the upper and lower ends of the surface 43a in FIG. 3. The upper and lower ends of the surface 43a of the substrate 43 correspond to a second portion thereof. Namely, the short electrical components are arranged

relatively closer to the central axis L, while the tall electrical components are arranged relatively farther from the central axis L. As arranged above, the motor drive circuit 41 is installed to the compressor housing 11 in such a manner that the electrical components 44 on the surface 43a of the substrate 43 line the cylindrical surface R of the circumferential wall 23. Incidentally, the switching device 44A, the electrolytic condenser 44B and the transformer 44C each are plurally arranged in the direction of the central axis L.

A clearance between the bottom surface 35a and the top surface 35c is relatively narrow at the middle region of the accommodating space 35 in the accommodating portion 36, and the short electrical components such as the switching device 44A are arranged at the middle region of the accommodating space 35. Clearances between the bottom surface 35a and the top surface 35c are relatively wide at both end regions relative to the middle region of the accommodating space 35, and the tall electrical components such as the electrolytic condenser 44B and the transformer 44C are arranged at the above end regions. Namely, the bottom surface 35a of the accommodating space 35 includes a convex surface at its middle where the bottom surface 35a approaches the top surface 35c to the maximum.. Accordingly, in comparison to an accommodating space that includes an entire planar bottom surface, the accommodating space 35 partially forms the shape along the cylindrical surface R of the circumferential wall 23.

In the motor drive circuit 41 in the accommodating space 35, the electrical components 44 are arranged on the surface 43a of the substrate 43 along the cylindrical surface R of the circumferential wall 23. Therefore, the motor drive circuit 41 is arranged to approach the central axis L of the motor compressor 10 because the electrical components 44 line the cylindrical surface R of the circumferential wall 23.

The substrate 43 is arranged at a distance of h4 from the cylindrical surface R. The distance h4 is shorter than the height h1 of the electrolytic condenser 44B that is the tallest in the electrical components 44. The cylindrical surface R of the circumferential wall 23 approaches the surface 43a of the substrate 43 without any interference with the electrical components 44 on the surface 43a, that is, without crossing the electrical components 44 on the surface 43a. Namely, the motor drive circuit 41 is arranged near the central axis L of the motor compressor 10 so that the cylindrical surface R of the circumferential wall 23 is arranged at the distance h4 from the substrate 43 and the distance h4 is shorter than the height h1 of the electrolytic condenser 44B.

In the preferred embodiment, "the electrical components 44 line the cylindrical surface R of the circumferential wall 23" means a state where the the cylindrical surface R of the circumferential wall 23 approaches the surface 43a in

such a manner that the distance h4 from the substrate 43 at least becomes shorter than the height h1 of the electrolytic condenser 44B while the cylindrical surface R of the circumferential wall 23 does not interfere with the electrical components 44 on the surface 43a.

Particularly, in the preferred embodiment, the cylindrical surface R of the circumferential wall 23 approaches the surface 43a of the substrate 43 in such a manner that the distance h4 from the substrate 43 becomes shorter than the height h2 of the transformer 44C, which is the second tallest, and the cylindrical surface R does not interfere with the electrical components 44 on the surface 43a. Accordingly, the electrical components 44 on the surface 43a adjacently line the cylindrical surface R of the circumferential wall 23 so that the motor drive circuit 41 is arranged near the central axis L much closer.

In the motor drive circuit 41, the switching device 44A, the electrolytic condenser 44B and the transformer 44C are in contact with the bottom surface 35a of the accommodating space 35 through a sheet or an insulating member 45 made of rubber or resin. Namely, the sheet 45 is interposed between the electrical components 44A, 44B, 44C and the first housing element 21 made of aluminum, respectively. A material having properties of relatively high elasticity and/or relatively high heat conductivity is employed as the sheet 45. A clearance between the top surface 35c of the cover member 38 and the motor drive circuit

41 is filled with a filler or an insulating member 46 made of rubber or resin. The filler 46 has properties of relatively high elasticity and/or relatively high heat conductivity.

According to the preferred embodiment, the following advantageous effects are obtained.

(1) The short electrical components, such as the switching device 44A, are mounted on the surface 43a on the near side relative to the central axis L of the motor compressor 10 and are arranged closer to the central axis L. In addition, the tall electrical components, such as the electrolytic condenser 44B and the transformer 44C, are arranged on the surface 43a of the substrate 43 and are arranged farther from the central axis L. This arrangement allows the electrical components 44 on the surface 43a to line the cylindrical surface R of the circumferential surface 23. The accommodating portion 36 on the compressor housing 11 defines the accommodating space 35 for accommodating the motor drive circuit 41 in such a manner that the accommodating space 35 is formed along the cylindrical surface R of the circumferential wall 23.

Accordingly, in the motor drive circuit 41 accommodated in the accommodating space 35, the electrical components 44 on the surface 43a of the substrate 43 line the cylindrical surface R of the circumferential wall 23. Since the

electrical components 44 line the cylindrical surface R, the motor drive circuit 41 is arranged relatively close to the central axis L of the compressor housing 11. Thus, the protrusion of the motor drive circuit 41 from the compressor housing 11 in the direction perpendicular to the central axis L is controlled at a relatively small amount so that the motor compressor 10 becomes small in diameter.

Furthermore, the motor drive circuit 41 is arranged close to the central axis L of the motor compressor 10, which means that a wall or a material, such as the casing seat 105 shown in FIG. 5, is reduced in thickness between the motor drive circuit 41 and the compressor housing 11. Accordingly, the motor compressor 10 becomes light in weight and becomes low-cost due to the reduction in the material. Furthermore, some trouble, such as a mold cavity, does not substantially occur in the die-cast compressor housing 11 due to the reduction in the material.

(2) On the surface 43a of the substrate 43, the short electrical components such as the switching device 44A are arranged at the middle portion, and the tall electrical components such as the electrolytic condenser 44B and the transformer 44C are respectively arranged on both sides to the middle portion. Thus, the tall electrical components are distributed on both sides to the short electrical components so that many of the electrical components 44 line the circumferential direction of the circumferential wall 23. Accordingly, the substrate 43 is prevented

from enlarging in size in the direction of the central axis L. That is, the motor compressor 10 is prevented from enlarging in size in the direction of the central axis L, while it is effectively reduced in size.

(3) In the accommodating portion 36, the compressor housing 11 defines the bottom and side surfaces 35a, 35b of the accommodating space 35. Accordingly, in comparison to an accommodating portion that is independent to the compressor housing 11, for example, the casing 106 illustrated in FIG. 5, the number of components is reduced in the motor compressor 10. Additionally, the compressor housing 11 having relatively high rigidity surrounds the motor drive circuit 41 and effectively protects the motor drive circuit 41 against an impact from the outside.

(4) On the substrate 43 on the near side relative to the central axis L, the electrical components 44A through 44C are in contact with the bottom surface 35a of the accommodating space 35 through the insulative sheet 45. In comparison to a state when an insulating space or a relatively large space is defined between the electrical components 44A through 44C and the bottom surface 35a of the accommodating space 35, the motor drive circuit 41 is arranged closer to the central axis L in the preferred embodiment. Accordingly, the motor compressor 10 is further reduced in size and weight. Additionally, in comparison to a state when an insulating space is defined, heat generated from the electrical components

44A through 44C is efficiently conducted to the compressor housing 11 so that the motor drive circuit 41 is efficiently cooled.

Furthermore, when the sheet 45 employs a material having relatively high heat conductivity, it contributes to further efficiently cooling the motor drive circuit 41. Meanwhile, when the sheet 45 employs a material having relatively high elasticity, it contributes to protecting the motor drive circuit 41 against an impact from the outside. In addition, the sheet 45 elastically deforms to cancel a dimensional tolerance so that the electrical components 44A through 44C are in firmly contact with the bottom surface 35a of the accommodating space 35. This leads to improvement in heat radiation performance of the electrical components 44A through 44C to the compressor housing 11.

(5) The metal cover member 38 is fastened to the compressor housing 11 for defining the top surface 35c of the accommodating space 35. The insulative filler 46 is interposed between the top surface 35c and the motor drive circuit 41. The combination of the metal cover member 38 and the metal compressor housing 11 surrounds the motor drive circuit 41. Accordingly, electromagnetic wave generated by the motor drive circuit 41 is prevented from leaking outside for efficiently suppressing noise toward the other electrical components.

Furthermore, in comparison to an insulating space or a large space is

defined between the motor drive circuit 41 and the top surface 35c of the accommodating space 35, the filler 46 is interposed between the motor drive circuit 41 and the top surface 35c of the accommodating space 35 so that the top surface 35c is arranged relatively close to the central axis L, that is, the cover member 38 is arranged relatively close to the central axis L. Accordingly, the motor compressor 10 is further reduced in size. Also, in comparison to a state when an insulating space is defined, heat generated by the motor drive circuit 41 is efficiently conducted through the cover member 38 so that the motor drive circuit 41 is efficiently cooled.

When the filler 46 employs a material having relatively high heat conductivity, it contributes to further efficiently cooling the motor drive circuit 41. Meanwhile, since the filler 46 employs a material having relatively high elasticity, it contributes to protecting the motor drive circuit 41 against an impact from the outside. In addition, the filler 46 elastically deforms to cancel a dimensional tolerance so that the motor drive circuit 41 is in firmly contact with the cover member 38. This leads to improvement in heat radiation performance of the motor drive circuit 41 to the cover member 38.

The present invention is not limited to the embodiments described above but may be modified into the following alternative embodiments.

In alternative embodiments to the above preferred embodiment, referring to FIG. 4, a diagram illustrates a partially enlarged cross-sectional view of a motor compressor. When the motor compressor has a relatively large space in the direction of the central axis L for mounting the electrical components 44, the tall electrical components such as the electrolytic condenser 44B is arranged on one side to the short electrical components such as the switching device 44A in the motor drive circuit 41. Additionally, the transformer 44C is not shown in the drawing. However, the transformer 44C is arranged on the surface 43a on the far side relative to the central axis L in such a manner that the electrolytic condenser 44B and the transformer 44C line in the direction of the central axis L.

In alternative embodiments to the above preferred embodiment, an electric motor and a compression mechanism are respectively accommodated in different compressor housings in a motor compressor. In this state, a motor drive circuit is arranged in one of the compressor housing that accommodates the electric motor and the other that accommodates the compression mechanism.

In alternative embodiments to the above preferred embodiment, the motor compressor is a hybrid compressor that includes two drive sources for driving the compression mechanism 26. The two drive sources are an electric motor and an engine for driving a vehicle.

In alternative embodiments to the above preferred embodiment, the compression mechanism 26 is not limited to a scroll type. For example, a piston type, a vane type and a helical type are applicable.

Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein but may be modified within the scope of the appended claims.